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STUDIES OF ORAL READING--XI. THE EYE-VOICE SPAN--READING EFFICIENCY AND SYNTACTIC PREDICTABILITY.

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THE RELATIONSHIPS BETWEEN READER EFFICIENCY IN PROCESSING SENTENCES AND DIFFERENCES IN THE DEEP STRUCTURE OF THE STIMULUS SENTENCES WERE STUDIED. THE EFFICIENCY OF PROCESSING, AS MEASURED BY THE SUBJECTS' EYE-VOICE SPAN, VARIED WITH CHANGES IN THE DEEP STRUCTURE. COMPARISONS WERE MADE BETWEEN READER PROCESSING OF PAIRS OF SENTENCES IN WHICH THE SURFACE STRUCTURE WAS THE SAME, BUT IN WHICH THE DEEP STRUCTURE WAS DIFFERENT. THE EYE-VOICE SPAN MEASURE VALIDLY DISCRIMINATED BETWEEN SENTENCES WITH THE SAME SURFACE STRUCTURE BUT WITH DIFFERING DEEP STRUCTURE. THE RESULTS WERE INTERPRETED TO SUGGEST VERY TENTATIVELY THAT THE EFFICIENCY OF READING PROCESSING IS (1) A FUNCTION OF THE "CONGRUENCE" OR "CONSTRAINTS" BETWEEN THE SURFACE STRUCTURE AND THE DEEP STRUCTURE OF SENTENCES, AND ALSO (2) A FUNCTION OF THE NUMBER OF STRUCTURAL "CATEGORIES" REQUIRED IN THE DEEP STRUCTURE. (AUTHOR/MC)

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Studies of Oral Reading:

XI. The Eye-Voice Span:

Reading Efficiency and Syntactic Predictability [1]

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ABSTRACT

This experiment studies the relationships between reader efficiency in processing sentences and differences in the deep structure of the stimulus sentences. The efficiency of processing, as measured by Ss' Eye-Voice Span, was found to vary with changes in the deep structure. Comparisons were made between reader processing of pairs of sentences in which the surface structure was the same, but in which the deep structure was different. The Eye-Voice Span measure was found to validly discriminate between sentences with the same surface structure but with differing deep structure. The results were interpreted to very tentatively suggest that the efficiency of reading processing is (1) a function of the 'congruence' or 'constraints' between the surface structure and the deep structure of the sentence, and also (2) a function of the number of structural 'categories' required in the deep structure.

1/ This research is supported by funds from the U.S. Office of Education.

This experiment studies the relationships between efficiency in reading and differences in the deep structure of the stimulus sentences. Thus, the experiment seeks to determine if differences at the deep structure level of sentences with the same surface phrase structure will effect the reader's processing behaviors — that is, (1) "Is sensitivity to deep structure reflected in reading processing?" Further, the experiment seeks to determine what effect the contrasting deep structures assigned to sentences which are superficially similar will have on reading efficiency — that is, (2) "Given a sentence with a specified deep structure, what can be predicted about the relative efficiency with which it can be processed?"

The distinction made here between 'deep structure' (DS) and 'surface structure' (SS) is that expressed by transformational grammar.[2] Transformationalists maintain that (1) the language user is intuitively aware of differences between DS and SS; and further, that (2) sentences can only be understood through a reconstruction of the sentence's 'structural description', including its DS.[3] This study tests the suitability of the theoretical distinction between DS and SS in explaining the efficiency of information input and processing in reading.

Recently, there have been contradictory research findings about the language user's sensitivity to DS. Mehler ("What We Look at When we Read"; 1966) found in observing Ss' eye-fixations for ambiguous sentences: "The structure which differed only at the deep phrase

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2/ See, for example Jerrold J. Katz's The Philosophy of Language (1966), and Noam Chomsky's Current Issues in Linguistic Theory (1964) and "Topics in the Theory of Generative Grammar" (1966).

3/ See, for example, George A. Miller and Chomsky's "Finitary Models of Language Users" (1963); and Chomsky's Aspects of the Theory of Syntax, (1965).

structure did not show such differences (in eye-fixation patterns as did the surface structure differences.)" However, Blumenthal ("Prompted Recall of Sentences"; 1966) and Blumenthal and Boakes ("Supplementary Report: Prompted Recall of Sentences"; 1967) indicate that "Recall differences correspond to the nature of the underlying grammatical relations."

In this study, the language-user's processing of linguistic material was measured by the Eye-Voice Span (EVS). In oral reading, the EVS is the distance, usually measured in words, that the 'eye' is ahead of the voice. The EVS was selected as the index for processing since recent work indicates that it is sensitive to grammatical constraints within the sentence. Schlesinger ("Sentence Structure and the Reading Process"; 1966) states that the EVS "represents a unit of decoding." Further, Levin and Turner ("Sentence Structure and the Eye-Voice Span"; 1966) have found that subjects tend to read in phrase units. Thus, they have shown the EVS to be sensitive to phrase structure. Also, Levin and Kaplan ("The Eye-Voice Span for Active and Passive Sentences"; 1966) found the EVS to vary in accordance with intrasentence constraints — They found that the EVS was related to sentence voice (passive versus active).

METHOD

Subjects Thirty Cornell University freshmen and sophomores, 15 males and 15 females, served as subjects.

Experimental Sentences Two kinds of passive sentence constructions were selected for this study. (See the Appendix for a list of the test sentences.) In the first type, the 'agent' or 'actor' was included while in the second, the agent was deleted. The sentences were paired so that the surface structure and lexical items were identical for both types of sentences, except that in one case the agent appeared, but in the other, the agent was deleted and replaced by a non-agentive form. For example:

(A) His brother was beaten up by the gang.

(B) His brother was beaten up by the park.

Both sentences A and B have the same surface structure:

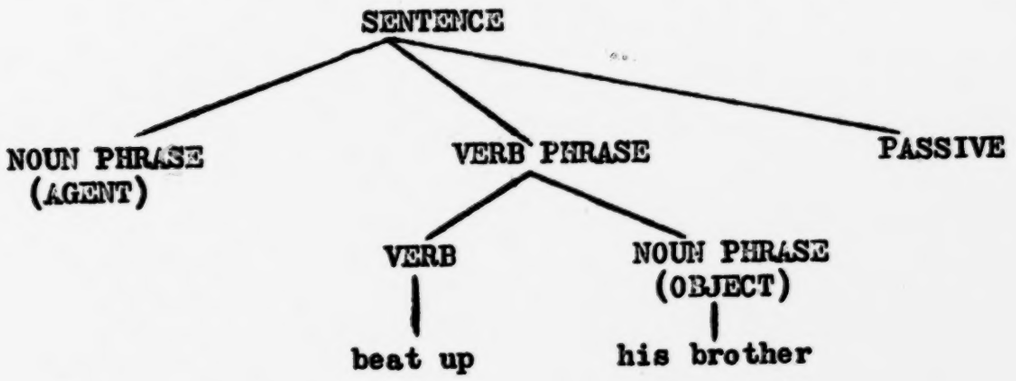
[His brother] [was [beaten up]] [by [the gang / park]]

The actual test sentences are longer than these, having approximately 18 words, with about 8 words after the light-out position, to take into account Ss whose EVS might tend to be relatively large.

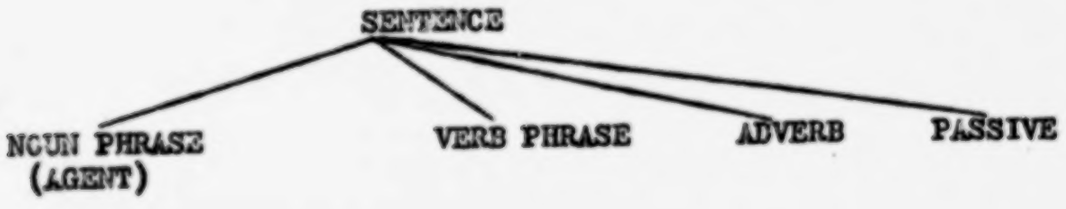
Both A and B contain the same lexical items except for one item. However, the substitution of "park" for "gang" in this case reflects a change in the DS of the sentence. In A, "gang" is the agent. In both A and B, "his brother" is the object of the verb "beat up", and someone or something else performed the action. Thus, A can be paraphrased as "The gang beat up his brother." Sentence B, on the other hand, cannot be paraphrased as "The park beat up his brother," since "park" is not the agent, but serves to indicate where the beating took place. An appropriate paraphrase would be: "His

brother was beaten up near the park." In order for one to understand these two sentences, one must know that "his brother" is the underlying object and that something else is the agent or actor. In the first case, "the gang" is the agent. In the second case, one must know that "the park" is not the agent, and that the action of beating was performed by some agent not specified in that sentence.

It was hypothesized that sentences of type A would be easier to process than sentences of type B since the DS in A was 'simpler' than in B. The DS for both A and B contain some of the same elements:



The DS in A is simpler for two reasons. First, the NOUN PHRASE — the AGENT NOUN PHRASE — is 'realized' in the surface structure as "the gang". Secondly, sentence type B requires an additional 'category slot' in the DS which is not required by type A. The description for the DS level for sentence type B would be like the following:



The ADVERB category slot must be realized in the DS because of the SS phrase "by the park". Type B is more difficult to process because in addition to requiring a slot for the underlying subject (the AGENT) even though it is not realized at the surface level, it requires a slot for the adverbial phrase which was substituted.

Since both kinds of sentences have the same surface structure, differences in the way in which they are processed can be attributed to differences in the deep structure. Further, since both kinds of sentences were of the passive type, requiring the 'surface subject' to be understood as the 'underlying object' of some action performed by the (specified or unspecified) underlying subject, it was hypothesized that the differences in processing would reflect the additional structure required at the underlying level in type B sentences.

Procedure To test the hypothesis that the efficiency of reading processing is related to the deep structure of the sentence, the EVS was used as a measure of language processing in reading. There were eight pairs of test sentences. In each pair, both sentences had the same structural description and the same lexical items, except for one item. Both sentences of each pair were imbedded in an identical context of five other sentences. The sentences in these 'paragraphs' were unconnected so that S's reading of the test sentences would not be affected by intersentential cues.

The test sentences were imbedded within 'paragraphs' so that even though S knew the light would be turned out while he was

reading the sentences in each 'paragraph', he did not know which sentence in the 'paragraph' would be treated as the 'critical sentence'. Also, even though every sentence position was treated as the critical position, none of the test sentences occurred in the first position (sentence position 1), so that S was able to read at least one sentence through completely before reaching a test sentence. In addition, no test sentence occurred in the last position (sentence position 6), so that the experimental results would not be affected by S's ability to predict that the light would be extinguished during his reading of the final sentence in the 'paragraph'.

In order to minimize memory interference and response set, the sentences were divided into two groups, with each group containing the other members of each of the eight pairs:

Set #1 (given at Time 1)	Set #2 (given at Time 2)
A 1	B 1
B 2	A 2
A 3	B 3
B 4	A 4
A 5	B 5
B 6	A 6
A 7	B 7
B 8	A 8

Each subject read all sixteen test sentences, eight at each of two sessions, spaced one week apart. In the first session, S read one member of each pair and in the second session, the other member.

In both sessions, Ss were presented with the eight paragraphs containing the critical sentences along with sixty-eight other paragraphs used as fillers between the test items. In both sessions identical filler paragraphs were used, and the order of presentation of all 76 (8 test and 68 filler) paragraphs was the same.

The paragraphs were typed single spaced on 9" x 5" cards so that Ss could read them as they would a regular 9" wide typed page. The cards were viewed one at a time by S. The viewing apparatus consisted of a wooden box approximately 24" x 18" x 12" with a one-way mirror through which S read the paragraphs. The cards were visible to S only when the light within the apparatus was on. The light was controlled by the experimenter who would extinguish the light and thus obscure the stimulus sentence when S reached the predetermined position for each paragraph.

S was instructed to begin reading each paragraph immediately when the light went on. He was told to read aloud at his normal rate, the rate at which he would read a story aloud to someone. He was told that within each paragraph, the light would be turned out so that he would no longer be able to see the text, and that he was to report all the words that he had seen but had not yet had a chance to read aloud. The light was turned out approximately an equal number of times in each of the six sentence positions, and within the sentences, the light was turned out at the beginning, middle, and end. The light-out position was varied to minimize Ss' response set. Of the eight pairs of critical sentences, two each appeared in sentence positions #2, #3, #4, and #5.

In four of the pairs of test sentences, the light was turned out immediately before the critical word reflecting a change in the underlying structure, and in the other four pairs, the light was turned out three words prior to the critical word. Two light-out positions were used because previous work by Levin[4] has shown that there is a significant interaction between light-out position, sentence structure, and reading processing as measured by the EVS. The light-out position immediately prior to the word reflecting a change in the DS (e.g., "gang" versus "park") was chosen since it was thought that the difference in reader response as measured by the EVS would be greatest at the point where the SS signalled the change in the DS. The light-out position three words prior to the critical word was used to determine how the reader's processing would differ at a point where the EVS would have picked up the SS cue, but prior to the point at which his oral reading had taken him to the critical word.

Scoring S had to recall a word perfectly in order for it to be included in his EVS score for a sentence. Thus, if a singular noun were changed to the plural form, or if a verb tense were changed, S's response was not counted. Also, no more than two words skipped could intervene between words actually recalled by S. This scoring procedure was used to minimize any distortion of the data resulting from the possibility that some S might skim to the end of a sentence without 'processing' the middle. Since

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4/ Levin and Turner, "Sentence Structure and the Eye-Voice Span", 1966; and Levin and Kaplan, "The Eye-Voice Span for Active and Passive Sentences", 1966.

these procedures required perfect recall of items in the SS and adherence to sequencing at the SS level, the scoring tended to favor surface structure over deep structure. For example, the ordering of structural elements would not necessarily be the same at the DS level as it is at the SS level; hence, scoring procedures which require S's recall to generally follow word order at the SS level are biased against DS. Also, requiring perfect recall of words, and consequently scoring as incorrect any changes in number (singular - plural) reflects a bias in favor of SS, for the 'number transformation' takes place at a low level within the structural description, proximate to the SS level. It is not something which is of high priority in the sentence's DS, since it is an obligatory mechanical process.

RESULTS

There were sixteen scores for each of the thirty Ss. The scores were averaged for each S so that there was a mean EVS score for type A sentences, and a mean EVS score for type B sentences. The scores were further broken down for the two light-out positions. In all cases what was being compared was S's EVS score for two sentences, one of type A, and one of type B, both with exactly the same surface structure, but with differing underlying structure. All the lexical items were identical except that in type A sentences the object of the preposition "by" was the agent (underlying subject), while in type B sentences the object

of the proposition "by" was a non-agentive noun telling where or when, not by whom, the action was performed.

When the light was turned out immediately prior to the critical word, the mean EVS score (30 Ss, 4 pairs of sentences apiece) for the agent-included (type A) sentences was 5.81 words, while for the agent-deleted (type B) sentences it was 5.21 words. The difference between the means, 0.60 words, is significant at the .002 level (2-tailed test) and compares closely with the results of a previous pilot study.[5/]

When the light-out position was three words prior to the critical word, the mean EVS scores (30 Ss, 4 pairs of sentences apiece) were in the same direction as above (5.13 words for agent-included sentences versus 4.94 words for agent-deleted sentences). As expected, the difference between the means was greater at the point where the SS signalled the difference at the DS level.

DISCUSSION

The experiment indicates that reader efficiency is related to the deep structure of a sentence. Since the sentences tested had the same SS, but differing DS, the difference between the means supports the hypothesis that the efficiency of language processing in reading is not solely dependent upon SS, but is related to DS. The EVS measure was found to be sensitive to differences at the DS level.

5/ The pilot study was run under essentially the same conditions with 10 Cornell graduate students as Ss and with the same or similar stimulus sentences (6 pairs of sentences apiece). The difference between the means for type A and type B sentences was 0.65 words.

In explaining the difference between the efficiency with which these two sentence-types were processed, one might argue that the individual lexical items appearing in the agent-included sentences were easier to process than the corresponding items in the agent-deleted sentences. This, however, seems unlikely, since both sets of words are quite common (See Appendix for a listing of these words). The explanation that objects of the prepositional phrases ("by the _____") of the sentences with the greater EVS appear more frequently in that context, and that such phrases are hence a more 'natural' part of the reader's linguistic repertory than the non-agentive phrases seems similarly unlikely. The grounds for saying that the phrase "by the gang" is more 'frequent' and consequently more easily processed than the phrase "by the park" must contend with the counter-argument that the frequency of occurrence of any particular phrase — or sentence, when compared to the indefinite number of possible phrases or sentences, is negligible.

'Naturalness', however, does appear to be a factor in the way these two structural types are processed. When the reader encounters a passive construction, some surface structure manifestation of the AGENT category is 'expected'. When the reader recognizes the verb form as marking the sentence to be a 'passive', the AGENT construction is somehow more 'predictable' or 'natural'. There is a strong correlation between judgments of 'naturalness' and size of EVS with respect to these agent-included versus agent-deleted sentence pairs.[6/]

6/ In a related experiment, 76 Ss were presented with a list of 23 sets of sentences, including 8 agent-included sentences paired with 8 agent-deleted sentences. They were asked to "Decide which sounds better or more natural to you." The agent-included type was judged more natural twice as often as its agent-deleted counterpart.

One might explain both findings (greater efficiency of processing and higher rating on naturalness) in terms of 'predictability of occurrence'. However, the 'predictability of occurrence' would not refer to the frequency of particular lexical items or of particular combinations of lexical items. Rather, 'predictability of occurrence' would refer to the co-occurrence of particular items as they are defined at the DS level. Thus, in terms of these two structural types, what the passive construction makes 'predictable' is a surface structure realization of the DS AGENT category. A noun phrase such as "the gang" can be the NP immediately dominated by the S constituent when the verb "beat up" is given — that is, "the gang" and "beat up (+ OBJECT)" can co-occur as NP and VP of S. This is not the case with "the park" when the verb "beat up (+ OBJECT)" is given as the VP of S.

Predictability would seem to apply to the occurrence of items as they are functionally defined at the DS level, within the context of the selectional restrictions, or constraints, specified by the SS realizations of the DS category slots. As the reader begins to pick up syntactic cues when he starts processing a sentence, what he has just encountered makes what is about to follow more predictable. (That is, if he has just 'read' the word "the", he would, on the basis of his previous linguistic experience, expect it to be followed by a noun such as "man", rather than by a verb such as "went".) This predictability is a function of the syntactic constraints holding between the lexical items in the sentence. For example, the syntactic cues that the reader could pick up as he begins processing

"His brother was beaten up by the ..." might include the following:

1) "was beaten up" signals the passive construction

2) "his brother", since it is the NP preceding the verb in a passive construction, is the OBJECT of the verb

3) some AGENT, as yet unspecified — i.e., not yet realized in the surface structure — "beat up his brother"

4) the syntactic features determining the verb "beat up" restrict the class of NPs which can co-occur as AGENT to those which have corresponding features — e.g., (+ ANIMATE)

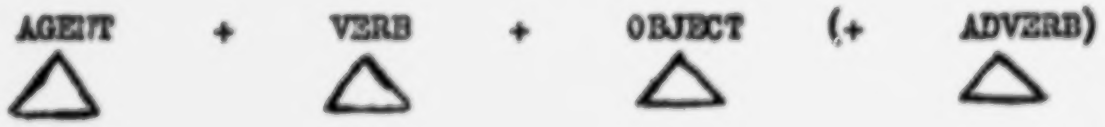
5) the presence of "by" here indicates that the NP functioning as AGENT is likely to follow. That is, the reader's previous experience with the preposition "by" occurring after the verb in a passive construction indicates that the AGENT is likely to be realized as the NP of "by"

Since all eight pairs of test sentences differed in the same respect (agent-inclusion versus agent-deletion), the experiment is tentatively interpreted to suggest that where categories specified in the DS are realized in the SS, reading processing is more efficient. That is, the reader is better able to process sentences in which there is a higher degree of 'syntactic congruence' or 'syntactic constraints' between the DS and SS levels. Of the two sentences discussed previously, A — "His brother was beaten up by the gang" — is more congruent to the DS

AGENT + VERB + OBJECT

since there is a closer correspondence between slots realized in the DS and in the SS levels:

Sentence B requires substantially the same DS description:



except that the congruence between the two levels is not as great as with A, since the underlying subject (the agent) is not realized in the SS. This congruence can be spoken of in terms of the syntactic constraints at the two levels of structure.

Thus, the syntactic features of the AGENT category, at the DS level, are realized at the SS level in "the gang", which has the same syntactic features. Hence, the co-occurrence of these features at the two levels establishes the syntactic constraints or congruence between these two elements. This congruence can be partially explained by the fact that "gang" is marked for the feature (+ ANIMATE), while "park" is marked for the feature (- ANIMATE). Consequently, "park" cannot be a realization of the AGENT category in this case. In both sentences, the relation of VP to S (that is, of VERB + OBJECT to SENTENCE) is the same as "beat up his brother" is to S. Also, the relation of NP (that is, of AGENT) to S, in sentence A, is the same as "the gang" to S. But this relation doesn't hold in B.

This is so because the syntactic features specified by the $\left\{\begin{matrix}NP \\ ; \\ S\end{matrix}\right\}$ are realized by "the gang" in A, but not by "the park" in B.

The experiment is also very tentatively interpreted to suggest that efficiency in reading processing decreases with the amount of structure that must be realized in the DS to accommodate the SS. Sentence B above, like all the agent-deletion test sentences, requires another slot at the DS level in addition to those required by the agent-inclusion test sentences. The degree to which the amount of DS - SS congruence facilitates reading processing, or the extent to which extra category slots at the DS level hinder reader efficiency cannot be determined from this experiment. However, this study shows that deep structure does affect processing of linguistic material by readers. Possible explanations for this phenomenon, including the effects of additional structure at the DS level and the effects of DS — SS congruence, will be tested in subsequent experiments.

LISTING AND EXPLANATION OF TEST SENTENCES

11. He knew that she was seriously injured by the / car (store) that was standing at the end of the alley.

17. His brother was beaten / up by the park (gang) that Fred had pointed out at the other end of town.

22. He had been / shot by the madman (restaurant) now being searched by detectives from the police station.

32. The speeding car was stopped by the / garden (police) where all the spectators were milling around.

35. If the lock was / fixed by the helper (time) you had promised us we would have paid you the full amount.

51. The rooming house that was / close by the University (closed by the University) had both male and female residents.

56. The door was opened by the / man (time) we had called and now we could once again use the garage.

62. He found out that his wife had been / attacked by the message (suspect) that the police brought over to his house.

The slash "/" marks the light-out position for each sentence. There were 4 instances in which the light was turned out immediately prior to the "critical word" (the word which serves to make the object of the by phrase the agent in the passive construction, or the word substituted for it): #11, #32, #51, and #56. In the other 4 instances, the light was turned out 3 words prior to the critical word.

The underlined word is the critical word which serves as agent for the passive construction.

The word in parentheses is the critical word which appeared in the sentence at the second test session in place of the preceding word. For example, in test session #1, each subject was presented the sentence: "He knew that she was seriously injured by the car that was standing at the end of the alley." At test session #2, the sentence was presented in the following form: "He knew that she was seriously injured by the store that was standing at the end of the alley."

The numbers preceding the sentences above refer to the sequence of the paragraphs in which each test sentence was imbedded. The order of presentation of the paragraphs (and, therefore, of the test sentences) was the same at both test sessions. The paragraphs in which each member of a pair of test sentences was imbedded was the same.